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Sequestering a persistent organochlorine with organic fertilizer and organic amendment to increase food safety in Martinique

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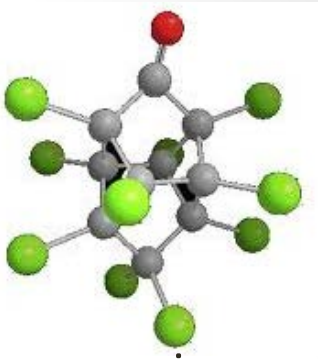
Context of pollution by chlordecone



- Persistent insecticide that was intensively used in banana cropping systems (1971→ 1993)
  - Physicochemical properties:
    - low solubility in water,
    - hydrophobicity,
    - which gives it a high affinity for organic matter
  - Poor biodegradability related to its peculiar chemical structure (bishomocubane) with high steric hindrance.

☞ **Natural decontamination would take decades / centuries**

(Cabidoche et al, Environ. Pollution, 2009)

- About 10 000 ha polluted at different levels

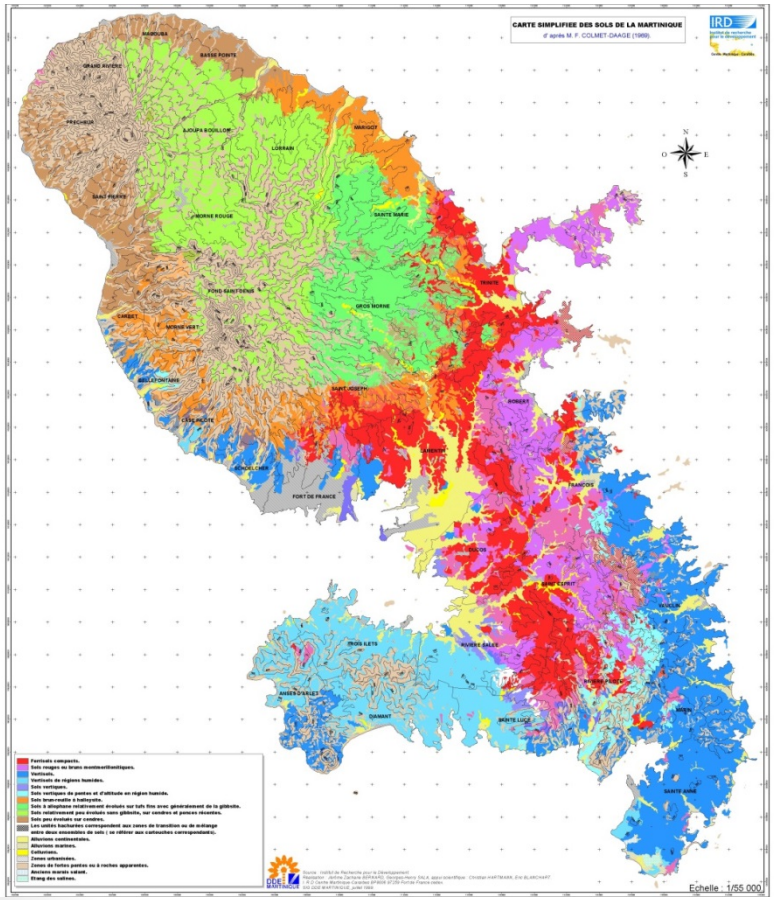
☞ **Need for efficient cost-effective *in situ* treatments.**

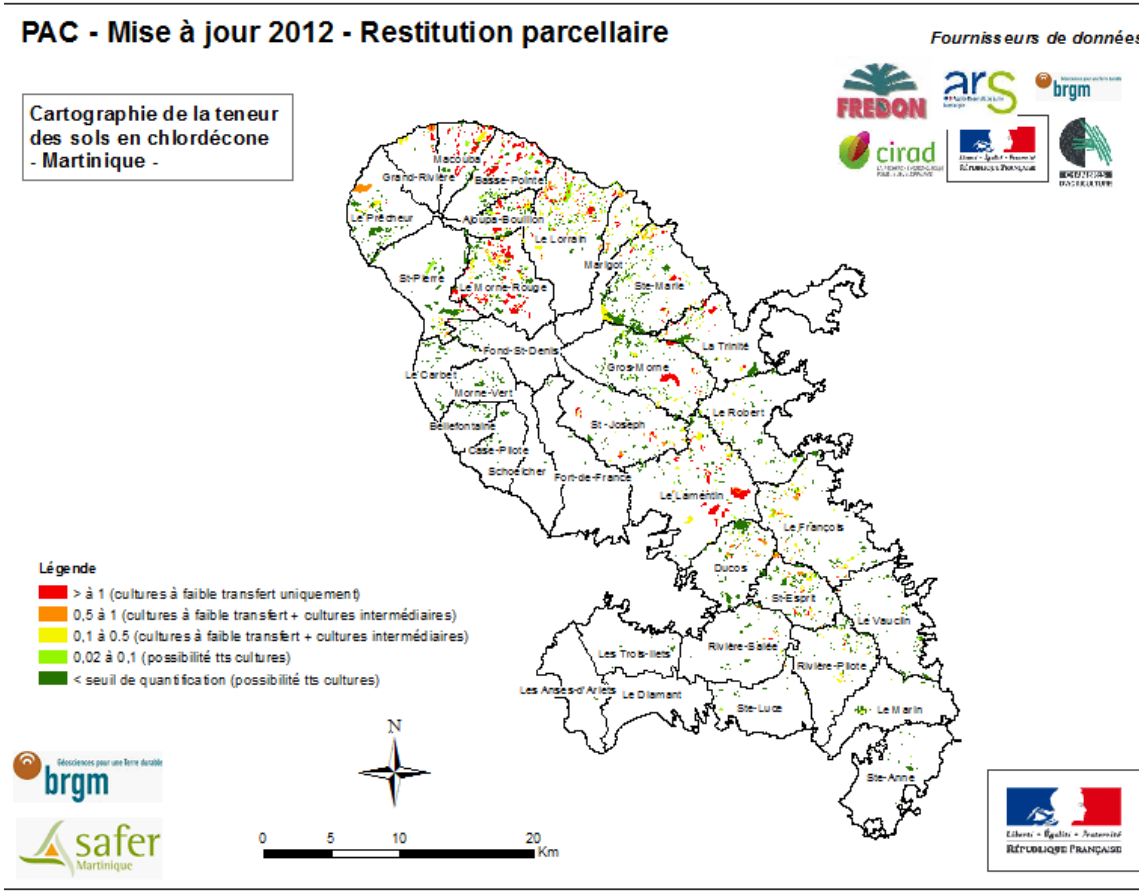
To date, phytoextraction *(Topp et al, Ecotoxicol Environ Saf, 1986)*

and microbial degradation *(George and Claxton, Xenobiotica, 1988 ; Orndorff and Colweel, Allpl Environ Microbiol., 1980)*

have not really been efficient in the case of diffuse pollution of chlordecone in the soil.

Soil types and polluted areas in Martinique

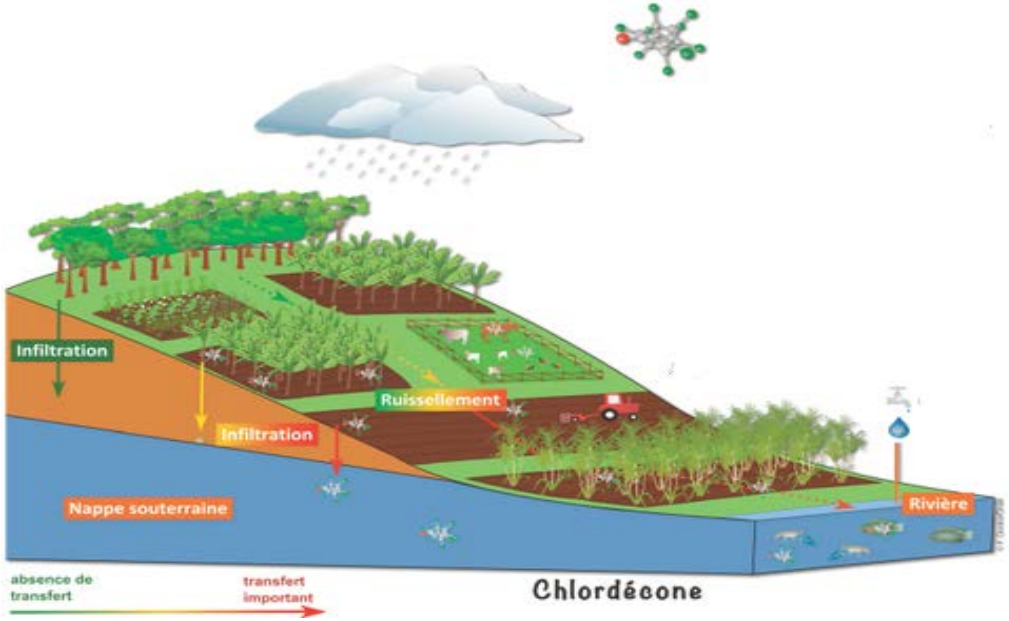




- Andosols and nitisols are the two main contaminated soil types

CHLD permanently pollutes soils…..

- …and consequently continues to contaminate crops, water resources, and food chains



☞ Consequences on human health, chlordecone is suspected to :

- be implicated in the increasing incidence of prostate cancer
  (Multigner et al, J Clin Oncol., 2010)
- impair development of young children
  (Boucher et al, Neurotoxicol., 2013 ; Dallaire et al, Envir. Res., 2012)

☞The release of chlordecone from polluted soils to food chains needs to be controlled to reduce contamination of products and populations.

CHLD sequestration by organic matter : dream or real alternative ?

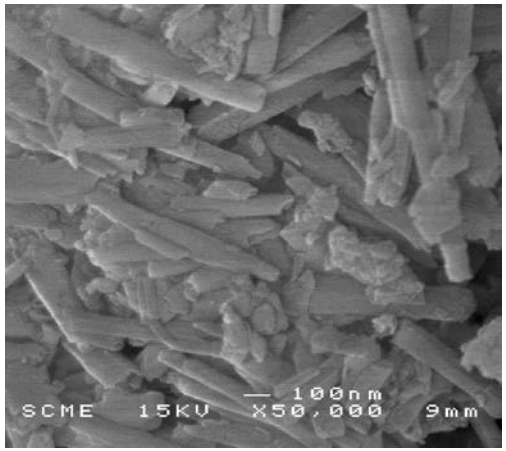
- Our main hypotesis

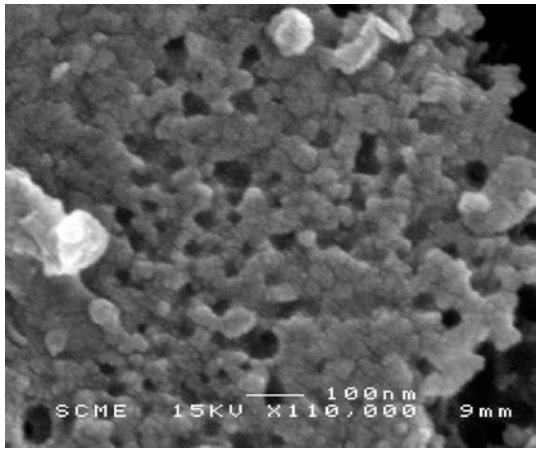
☞ **sequestering chlordecone in the soil could be an alternative way to reduce its availability for crops and water resources.**

- Our objectives
  1. To confirm that adding organic matter reduces CHLD contamination of the environnement
  2. To discuss the role of pore microstructure in the ability of a soil to trap CHLD

- We then chose to study the ability of two different organic matters to sequestrate this molecule in the two main contaminated soil types presenting different characteristics:
  - andosols, with amorphous clays (allophane),
  - and nitisols, with crystalline 1/1 clays.

Material and methods overview





+

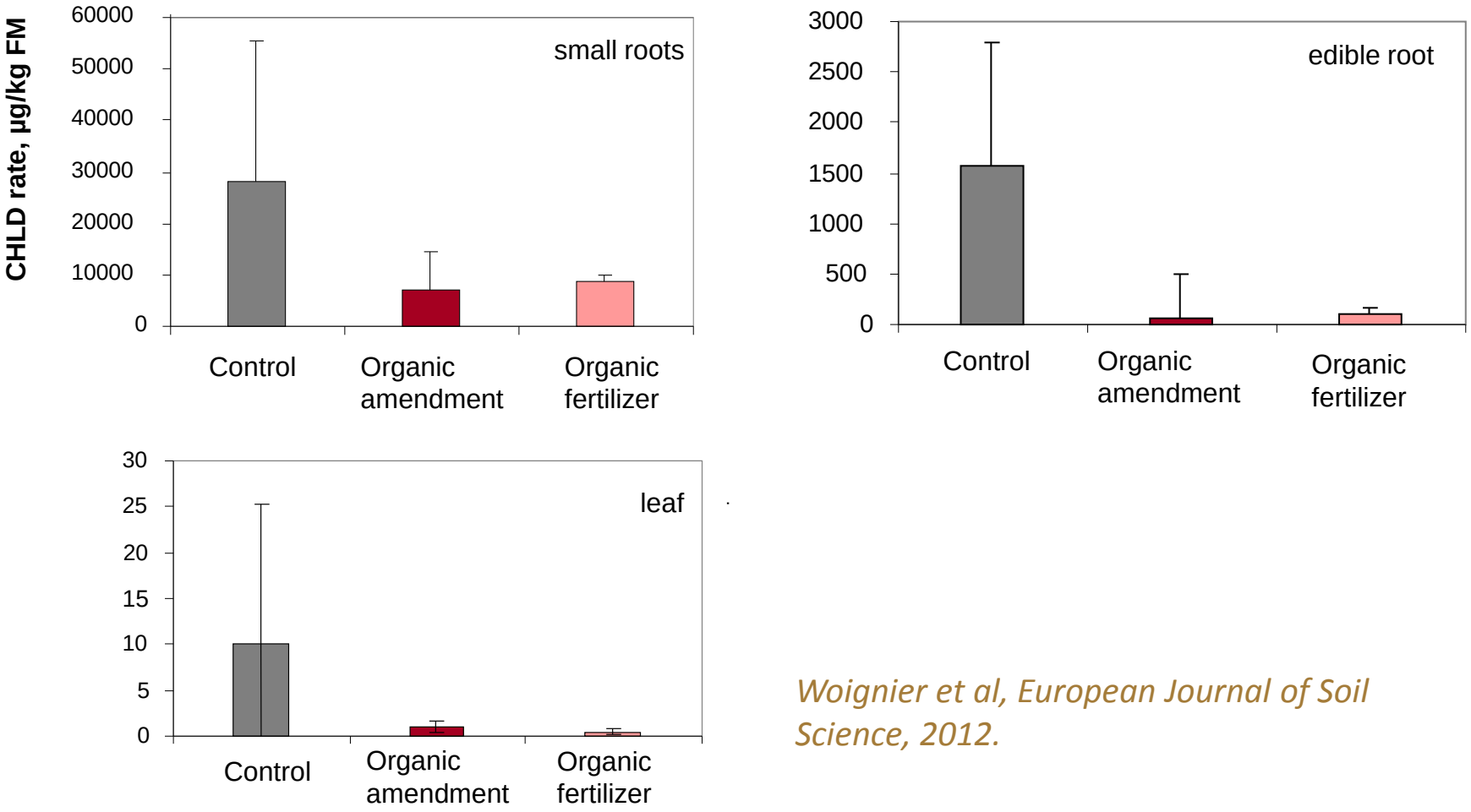
5% w/w

	Organic fertilizer	Organic amendment
Water content	47 %	24.8 %
Organic matter content	20.6 %	46.6 %
Humic yield (CBM)	49 kg C t^{-1} of fresh product	577 kg C t^{-1} of fresh product
Humifying capacity (k_1)	0.11	0.70

- CHLD contamination of crops
- CHLD leaching by water
- CHLD distribution in soil fractions
- Evolution of soil microstructure

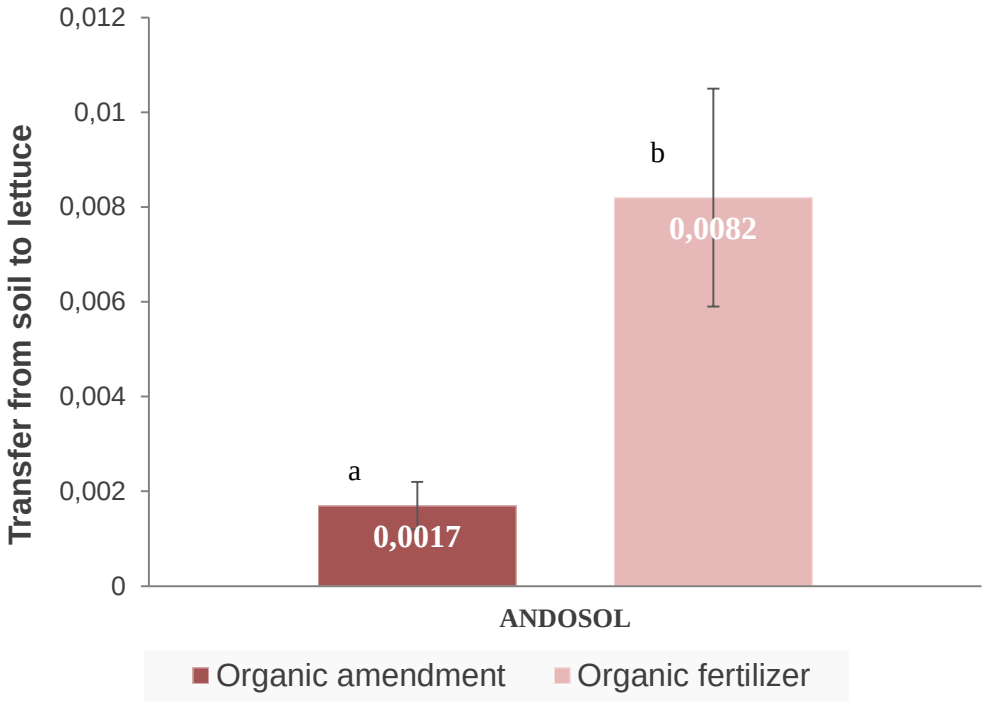
Added OM drastically reduced crop contamination by CHLD

Chlordecone content (µg/kg of fresh material) of radish cultivated on contaminated andosol, 3 months after OM addition - pot experiment



Woignier et al, European Journal of Soil Science, 2012.

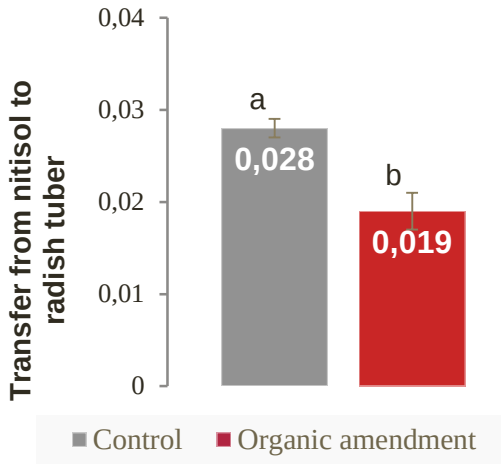
Added OM initial quality has an impact on the duration effect

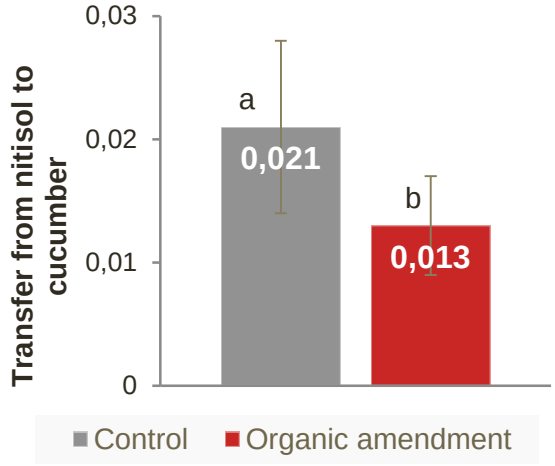


- No more significant effect on CHLD contamination with the organic fertilizer 6 months after addition - pot experiment
- Only the organic amendment still reduces the crop contamination (5 fold)

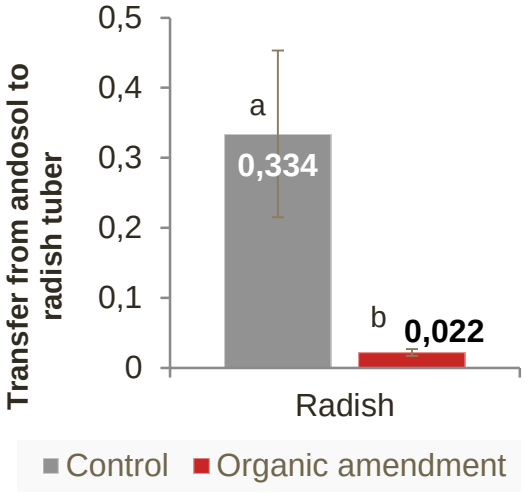
☞**focus on the organic amendment for the field evaluations**

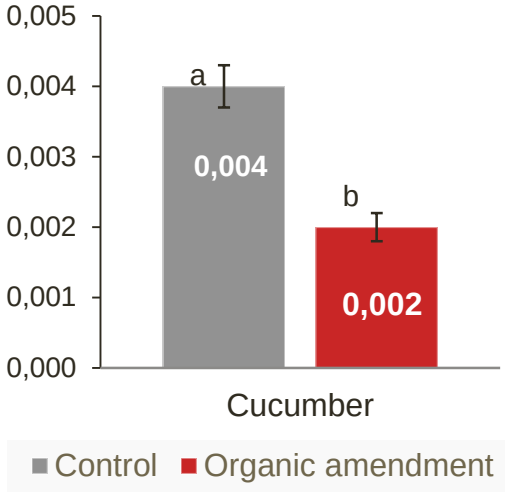
CHLD transfer between 3 and 6 months after OM incorporation at field scale





NITISOL



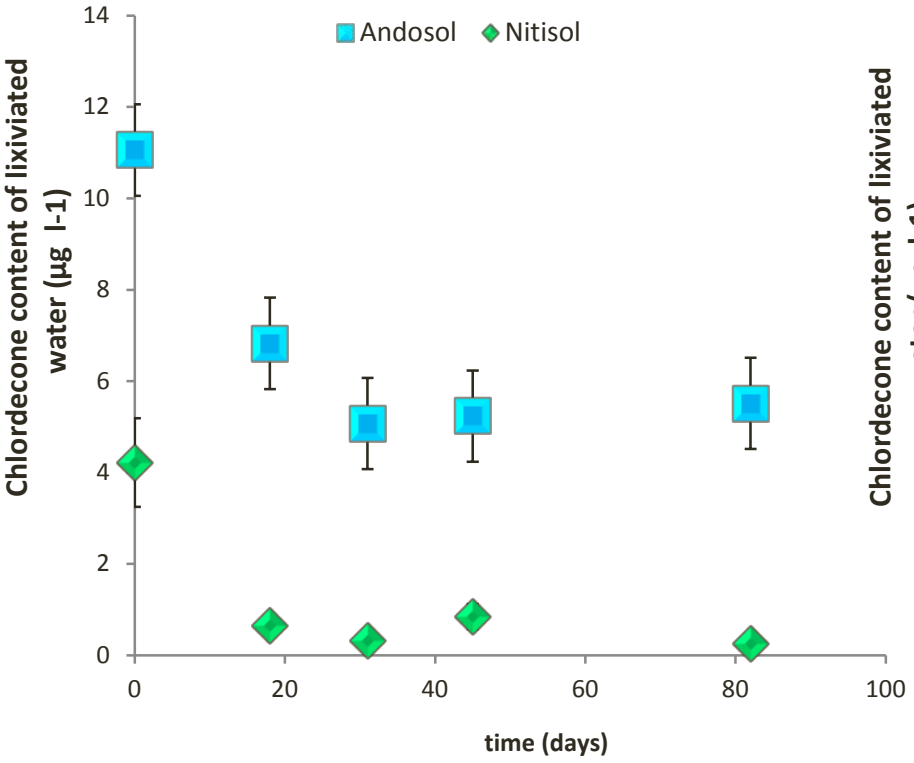


ANDOSOL

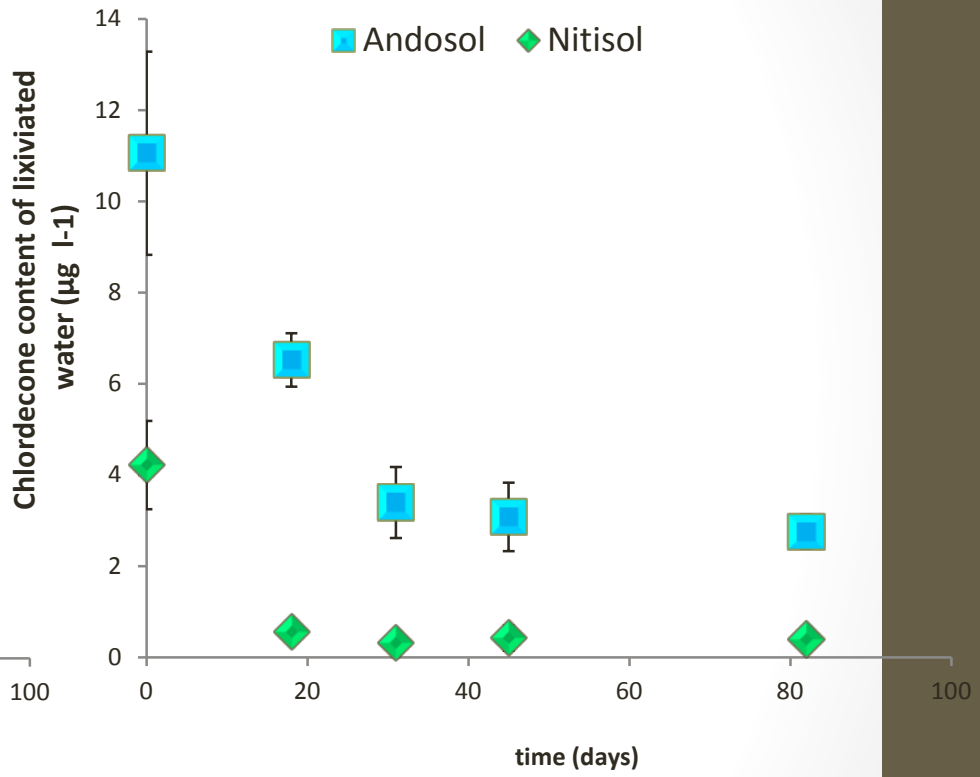
- Organic amendment still reduces significantly CHLD contamination but with lesser amplitude (1,4 to 15 fold)

Woignier et al, Fertilizer Technology vol 2, in press

Do added OM reduced water extractable CHLD ?



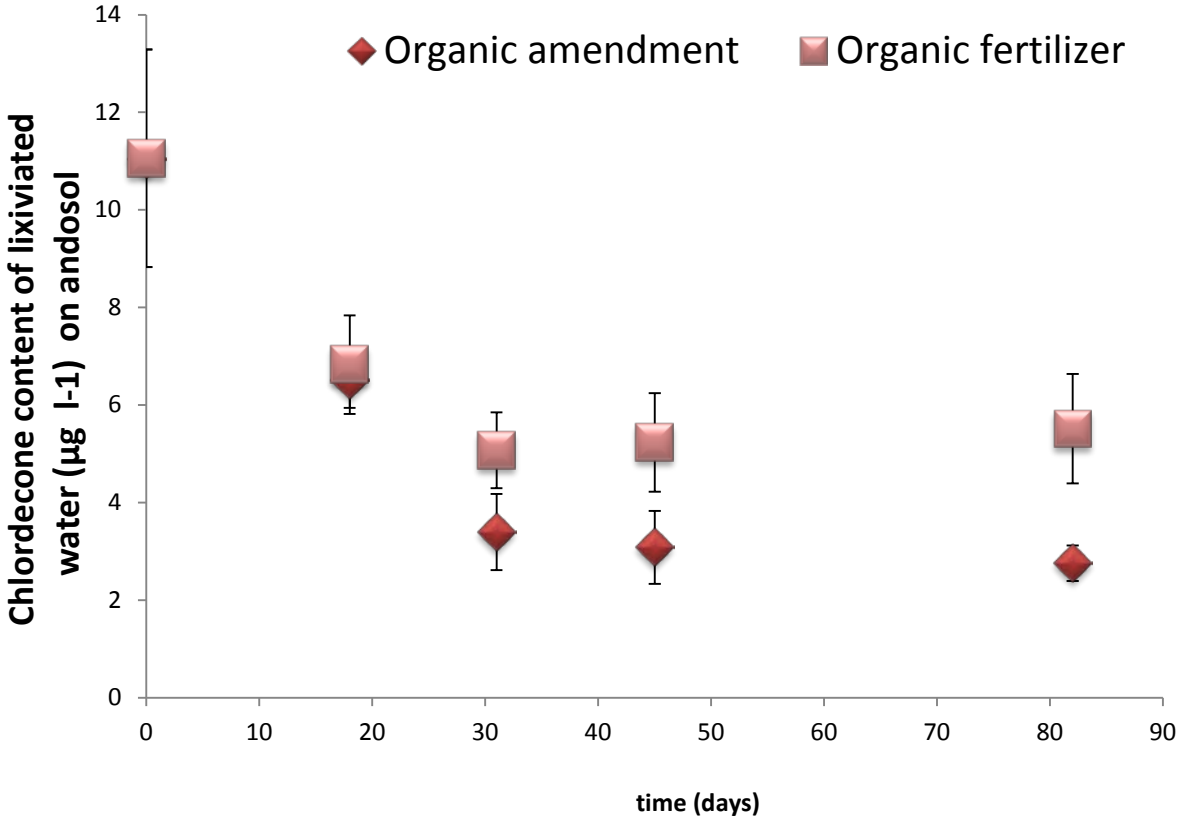
after organic fertilizer



after organic amendment

- OM quickly reduced water extractable CHLD in both soils

OM quality impacts the intensity of CHLD leaching



- The richest and more complex OM has a greater effect

Woignier et al, European Journal of Soil Science, 2012.

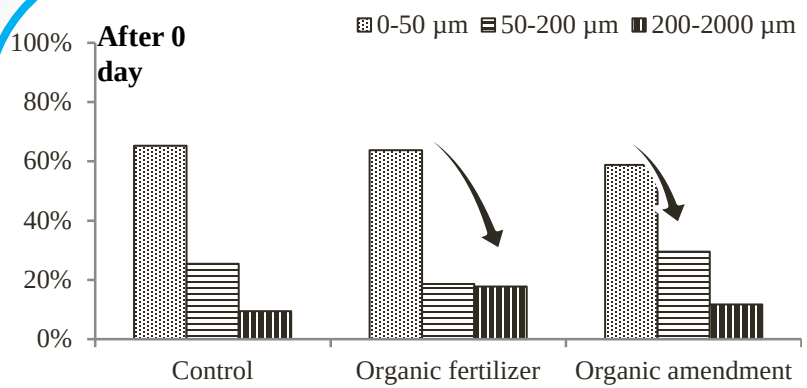
CHLD in soil fractions : effect of clay type

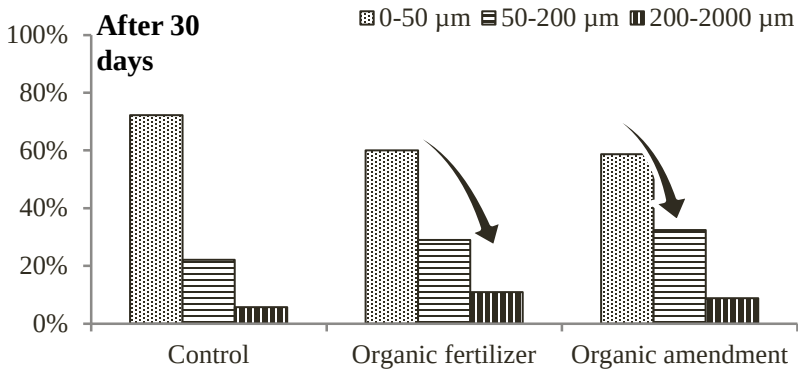
	CLD content (in mg CLD kg^{-1} dry soil)						ANOVA Pr> F
Soil type	fraction a		fraction b		fraction c		
Allophane	1.16 ± 0.39	a	2.14 ± 0.26	a	10.25 ± 4.2	b	0.007
Halloysite	0.66±0.11	a	0.99± 0.17	b	0.95± 0.07	a,b	0.031

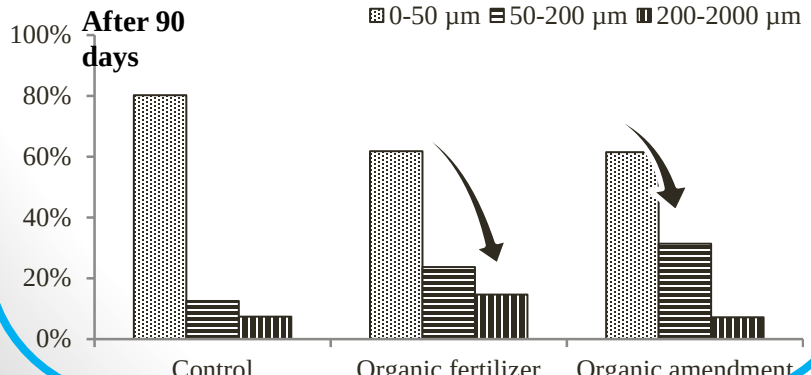
Fraction a : 200-2000 µm ; fraction b : 50-200 µm ; fraction c : 0-50 µm

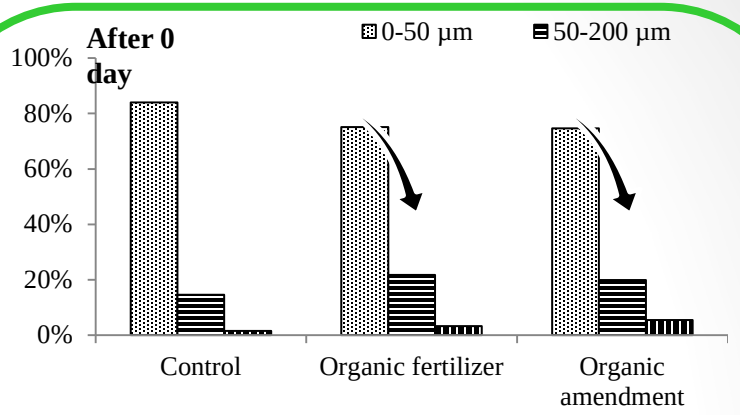
(Woignier et al, submitted)

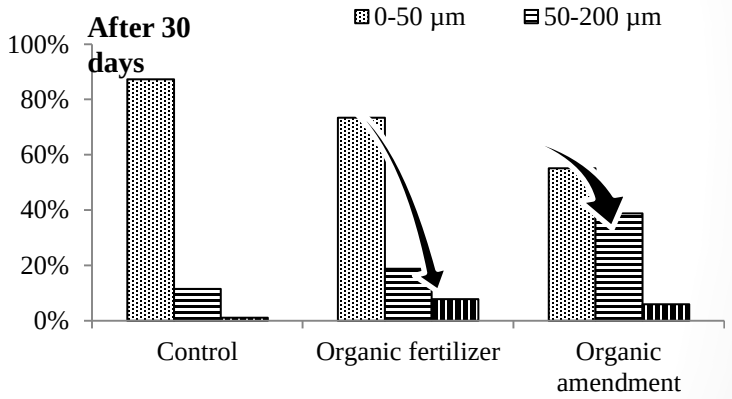
CHLD “migrate” in soil fractions depending on added OM granulometry

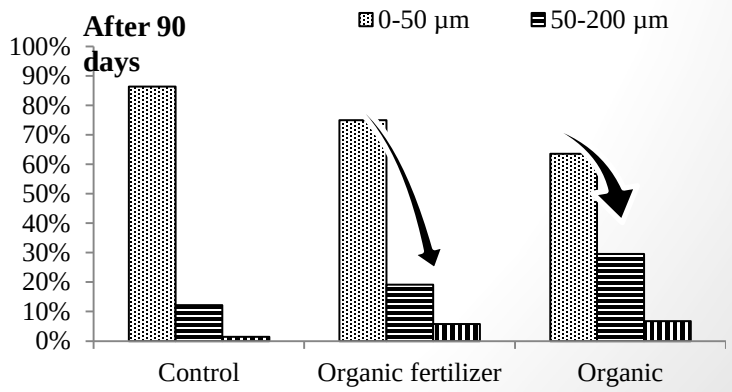




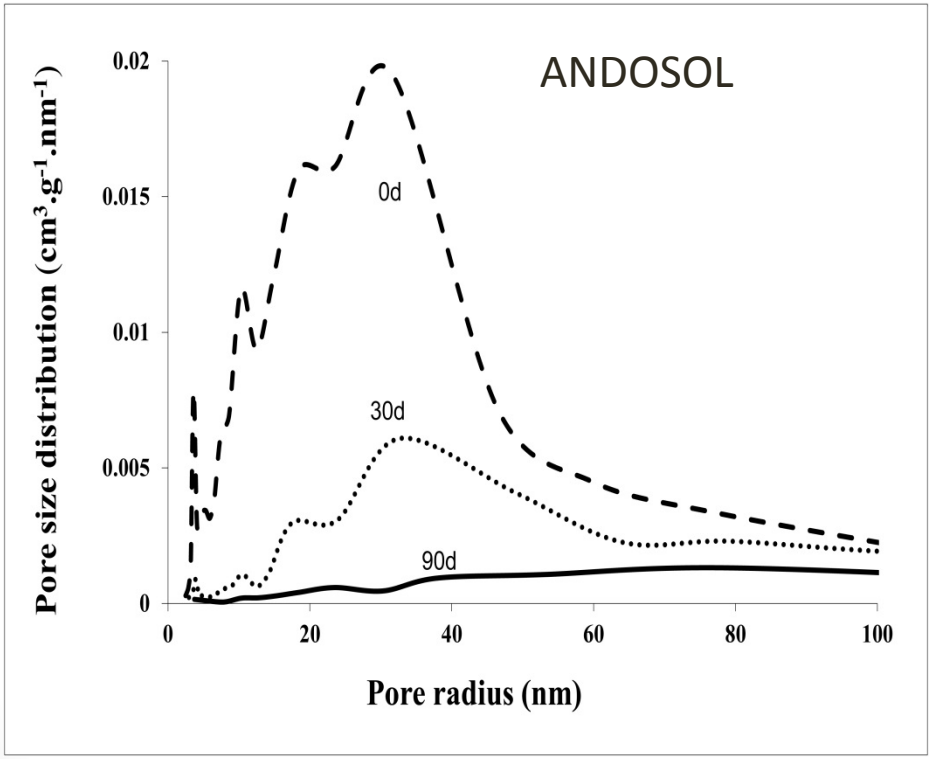


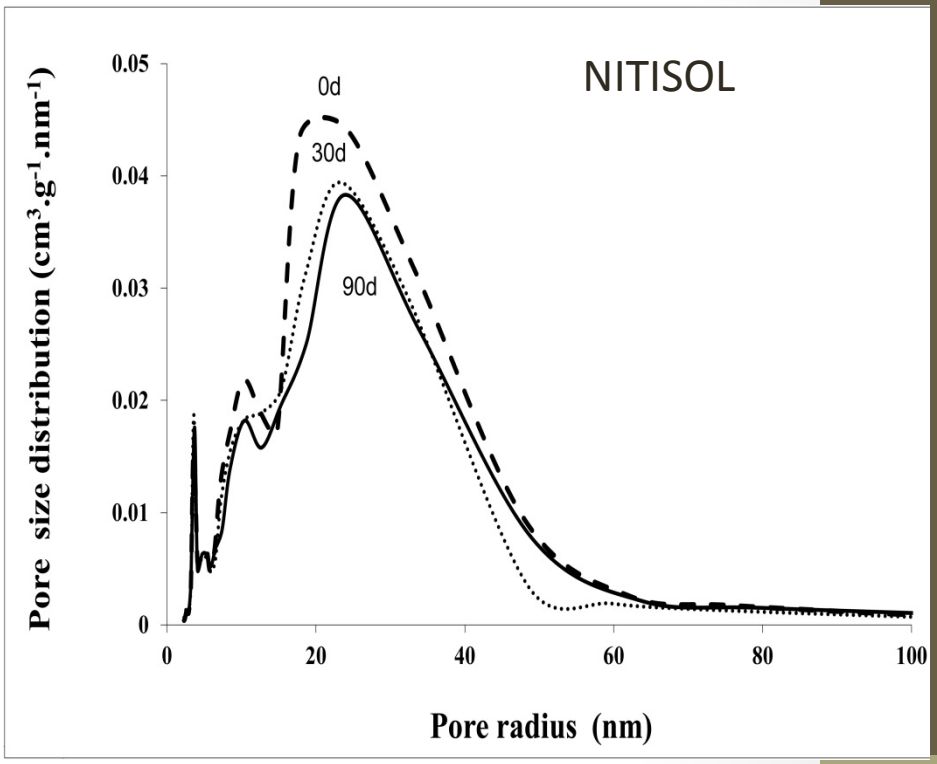






Added OM reduced mesopore volume in andosols but not on nitisols





- The mesoporosity of andosol decreased with added OM.
- After 30 days, the pore size distribution was reduced to one third of that at day 0, indicating pore closure in the range of 10 to 80 nm. After 90 days, the pore size distribution was still strongly affected by both composts (loss of 80% of the mesopores).

Added OM reduced mesopore volume in andosols

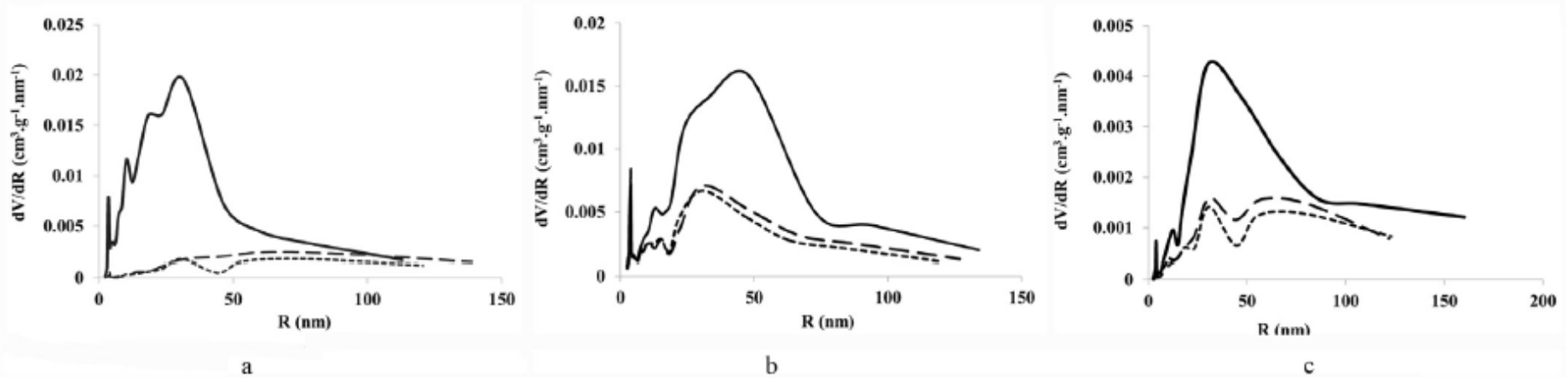
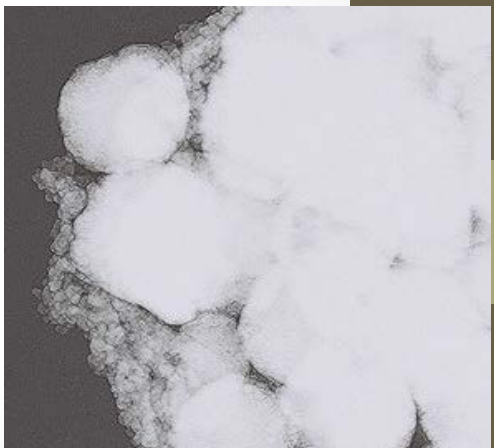


Fig. 4. Changes in pore size distribution after compost was added, at $t = 0$ day (continuous line), $t = 30$ days (dashed line) and $t = 90$ days (dotted line): 4*a* = 18% allophane andosol, 4*b* = 8% allophane andosol, 4*c* = 6% allophane andosol.

- The higher the allophane content, the wider the pore size distribution
- After incubation for 30 and 90 days, mesoporosity was strongly reduced
- After 30 days of incubation, most of the PSD was reduced by 30% 40% indicating a loss of pores in the size range 10–60 nm.
- After90 days, there was an 80% loss of mesopore volume in the soil containing 18% allophane.

Take home message

- Added OM can reduced crop contamination
- The intensity and duration of this effect depend on
  - initial chemical richness
  - biochemical composition of added OM
- Added OM act like a chemical attractant in nitisol (1/1 clay)
- Added OM induced a dramatic collapse of mesoporosity on andosol
  - CLHD physically trapped in a closed labyrinth



Special thought to….

- Yves-Marie Cabidoche (✞ 2012), soil researcher at INRA Guadeloupe, pionnier in the chlordecone working group and highly estimated colleague

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- French National Research Agency (Chlordexco project)
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- EU-FEDER research funds

☞ for supporting this pluriannual research program

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…working in an attractive scientific platform ….located in a beautiful environnement…

Thanks for your attention ! Any questions ?